Time limit at maximal aerobic power, heart rate kinetics and performance in time-trial cycling test of 3 km

https://doi.org/10.11606/issn.1981-4690.v35i4p171-180

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Abstract

The performance of cyclists in short terms workouts can be associate with several factors, including the maximal aerobic power (MAP), heart rate (HR) and its kinetics parameters, and the capacity to tolerate maximal efforts to exhaustion (TLimMAP). Thereby, the main of this study was analyze the presumable relation among TLimMAP and performance in a time-trial cycling test of 3 km (TT_{3km}). Seven cyclists were involved in this study, performing the following tests with a minimum interval of 48h: (1) initial familiarization and anthropometric evaluation, (2) maximal progressive test to exhaustion, (3) TLimMAP and (4) TT_{3km} test. There was a tendency of subjects with higher values to TLimMAP performed the TT_{3km} faster (r = -0,71; p = 0,07). It showed positive correlation among TLimMAP and the first time constant of the heart rate at the beginning of exercise (r = 0,95 e p < 0,01), and negative to TLimMAP and the first time constant of the heart rate recovery (r = -0,67 e p = 0,04). The tendency to association among the TLimMAP and performance at the TT_{3km} indicate that the TLimMAP could be utilized in the assessment of cyclists - although with caveats - since there was not significant correlation. Additional investigations to enlighten the relations among TLimMAP, HR kinetics and performance would characterize a proficuous field of research.

Keywords: Heart rate; Maximal aerobic power; Time-trial; Cycling.

Introduction

Investigations on physiological variables associated with performance in endurance sports have been a research focus for many years[1-4]. Particularly, in cycling, most of the aforementioned studies emphasize maximum oxygen uptake (VO_{2MAX}) as the main variable associated with sports performance. However, further investigatigations[5-6] suggested that, although being essencial to endurance athletes, VO_{2MAX} alone is not able to predict performance in homogeneous groups of athletes.

Therefore, new parameters were proposed to identify physiological responses that could be associated with cycling performance. Among them, time to exhaustion at power output corresponding to VO_{2MAX} (TLim), represents the maximal amount of time an indivudual is able to tolerate the intensity corresponding to VO_{2MAX}[6]. It is believed that TLim effiency is related to maximal aerobic power, movement economy, and neuromuscular parameters[6-7]. This seems to be particularly important, since maximal aerobic power[8], movement economy[9], and neuromuscular parameters[7] are determinants for the success of athletes in long duration events.

However, establishing TLim intensity from VO_{2MAX} is not accessible to amateur cyclists, for the necessity of expensive equipment and qualified professionals. A more affordable option is to determine TLim using peak power output (P_{MAX}) assessed in a single progressive test, as this variable is not significantly different from the minimal power output eliciting VO_{2MAX}[8]. Another alternative is to consider maximal heart rate (HR_{MAX}) to determine the load relative to TLim, for its dynamics is similar to VO_2[10], requiring less cost with equipments and tests.

Using TLim at maximal aerobic power ($TLimP_{MAX}$), associated with other variables related to HR, could be an accessible method for evaluating cycling performance, specialy if time analysis of HR is considered. Savin, Davidson and Haskell[11] demonstrated that lower values for time constant of cardiac kinetics (HR_{ON}) resulted in larger cardiac debts, and possibly, lower oxygen deficit at the onset of exercise. Individuals with such characteristics could evidence a better performance in competitions related to maximal aerobic power.

In relation to HR recovery kinetics (HR_{off}), an association between time constant and aerobic fitness is also verified[12], as a faster response in HR_{off} may be associated with increased autonomic vagal activity and increased capacity to recover from stress generated by maximal effort[13]. Other factors influencing cardiac kinetics are hemodynamics, structural, and functional cardiac aspects[14], autonomic nervous system intrinsic factors[15], individual characteristics (age and gender), along with exercise type and training volume[12]. However, it is important to emphasize that no investigations on HR response and $TLimP_{MAX}$ as possible performance indicators for mid duration cycling events were conducted.

The purpose of the present study was to verify if time to exhaustion at the correspondent maximal aerobic power ($TLimP_{MAX}$) and HR kinetics are associated with a 3 km time trial performance (TT_{3km}). We hypothesized that cyclists presenting higher $TLimP_{MAX}$ values and lower time constant of cardiac kinetics values, would have a better performance in the TT_{3km}.

Methods

Subjects

Participated voluntarialy of the presente study 7 recreational male cyclists (age = 35 ± 6; body mass = 75.5 ± 13 kg; height = 178.1 ± 10.7 cm; body fat = 15.6 ± 4.8 %), with a minimum of 12 months of practice, at least 3 training sessions per week and a weekly volume greater than 50 km. All subjects signed the informed concent form approved by the local Ethics Committee. Participants were asked to refrain from strenuous exercise, to abstain from alcohol or caffeine for 48 h prior to test. All procedures were executed two hours after the last meal, at the same time of day, with similar temperature (20º - 24º C) and relative humidity in air (60% - 80%).

Experimental Procedures

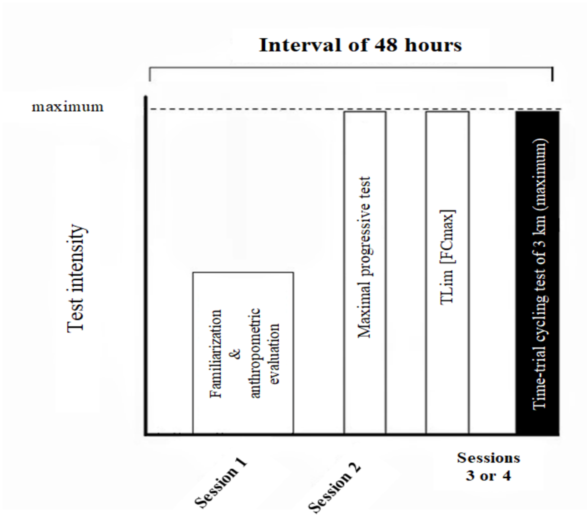
Participants came to the laboratory in four occasions (FIGURE 1), with a minimum interval of 48 hours and a maximum of 72 hours. On the first visit, subjects were submitted to anthropometric evaluations and familiarization with ergometers, to avoid possible learning effects on performance. Guedes equation[16] was used to estimate body density and Siri equation[17] for estimating body fat percentage (%BF).

On the second visit, volunteers performed a maximal incremental test on a cycle ergometer, for measuring maximal HR (HR_{MAX}), P_{MAX}, and anaerobic threshold (ANT) - detailed as follows. Subsequently, $TLimP_{MAX}$ and TT_{3KM} tests were performed, in random order from the third session onwards. Ergofit electromagnetic cycle ergometer (model 167, Germany) was used in both maximal incremental and TLimPmax tests, whilst TT_{3KM} was performed on a cycle simulator (Technogym, Italy). All TT_{3KM} sessions were performed on the same bicycle (mountain bike wheel 29) and with constant chainring-cassette ratio (38 x 22, respectively), in an attempt to minimize their influence on the performance[18, 19].

Maximal incremental test and constant load protocols

Initialy, participants remained seated on the cycle ergometer for 10 minutes at rest, for measuring basal HR and blood lactate $[La]_b$. After a 3-minute warm up with only the inertial resistance from the equipment, subjects cycled at 70 W for 3 minutes. Subsequent increments of 30 W at the final five seconds of every 3-minute stage continued, until subjects could no longer maintain pedaling frequency at 80 rpm for at least five seconds[20].

Anaerobic threshold (ANT) was established at a fixed $[La]_b$ of 3.5 $mmol.L^{-1}$ [21], expressed as the



Where TLimPMAX = time to exhaustion at peak power output, determined from maximal progressive test. Sessions 3 and 4 were performed in random order.

FIGURE 1 - Time line of experimental procedures performed by cyclists.

correspondent power output at ANT. HR_{MAX} was defined as the mean of the three higher values obtained at the end of the incremental test[22], and P_{MAX} was defined as the higher load achieved during incremental test. The following equation was used when the last stage was not completed:

$$\mathbf{W_{peak} = W_a + [(t \div 180 \cdot 30)]} \quad \textbf{(equation 1)}$$

W_{peak} = maximal aerobic power; W_a = power output at the previous stage before test interruption; t = time (s) subject maintain the incomplete stage; 180 = stage duration (in seconds); 30 = load increment for every consecutive stage (in watts). Equation adapted from Padilha et al.[23].

Time to exhaustion at peak power output

$TLimP_{MAX}$ was performed at the load corresponding to P_{MAX}, obtained at the end of the maximal incremental test. Subjects remained seated at rest for 10 minutes for registering HR, then performed a 30-second warm up at 80 rpm with only the inertial resistance of the equipment, followed by a load increment corresponding to P_{MAX}, maintaining the same pedaling frequency (80 rpm). Test was interrupted when subject could no longer maintain cadence for at least five seconds. The time duration that the subject tolerated the effort, recovery $[La]_b$ 10 minutes after protocol conclusion, and HR_{MAX} (obtained from the time interval between ventricular systoles), defined as the mean of the last 15 s before test interruption, were measured. Participants remained seated during all recovery.

TT^{3km} was performed on a cycle simulator, which allows power output increments, with a 2% incline. For all testings, an evaluator registered time, pedaling frequency, speed, and power output for every kilometer, for further analysis. Protocol started with a 5-minute rest in the seated position, for measuring baseline cardiac parameters and $[La]_b$, followed by a 3-minute warm up, with only the inertial resistance of the equipment at 80 rpm cadence. Test began subsequently; subject was instructed to performe in the least time possible, with self-selected strategy, speed and cadence. Similarly, to the other tests, HR and $[La]_b$ were measured during the 10-minute recovery, with subject at the seated position.

Analysis of blood lactate concentrations and cardiovascular parameters

Previously and immediately after progressive test, TT_{3km} and $TLimP_{MAX}$, as well as during the final 15 s of each progressive test stage, 25 µl of blood sample was collected for $[La]_b$ determination, with incision from the ear lobe after local asepsis and utilization of topic vasodilator (Finalgon®). Blood samples were immediately analized with a lactimeter (Yellow Springs Sport® - model 1500, Ohio, USA). HR was registered with a monitor (Polar S810-i) previously validated[24]. Data was recorded beat by beat, frequency acquisition of 250 Hz extrapolated to 1000 Hz, then transmited to a computer with the software Polar Precision Performance (version 4.00.024, Finland). All HR data was edited manually, excluding any data different from the previous in more than ± 3 standard deviations[25, 26].

As described previously[25, 27-28], for intensities above the very heavy domain of exercise, the kinetic adjustment which results in the lowest residual sum of squares to HR_{ON} would be a monoexponential function (equation 2), as for the HR_{OFF} (equation 3) would be a biexponential function, described in detail as follows:

BL corresponds to HR baseline values;
A1 and A2 represent the amplitude;
T1 and T2 correspond to time constant for fast and slow components, respectively.

HR(t) = LB + A1 (1 -e (-t / T1)) fast component (equation 2)

FC(t) = (A1 • -e (-t / T1)) + fast component (equation 3)

(A2 • -e (-t / T2)) + LB slow component

A linear function was used to describe possible variations in HR_{OFF} after manifestation of the slow component. Angular coefficient values of HR > ±0.01 $bpm.min^{-1}$ after HR_{OFF} estabilized were disregarded from analysis. This criterion was used previously by Bearden and Moffatt[27] to identify HR steady-state and asymptotic behavior of HR recovery kinetics that would allow a biexponential fit. Initially, alterations were identified by visual analysis, and then confirmed by linear adjustments of one minute segments. Apart from the kinetic response, the mean HR for $TLimP_{MAX}$ and TT_{3km} tests was calculated during the first 6 minutes after exercise interruption, established from the last five seconds from each minute (immediately, two, four, and six minutes).

Statistical analysis

Data was analized with statistical software (SPSS – 13.0) and described as mean ± standard deviation. Initially, the normality of P_{MAX} and HR values was verified (Shapiro-Wilk test), then Pearson product-moment correlation coefficient was used to describe assossiations between $TLimP_{MAX}$ and on and off heart rate kinetics. For all analysis, the level of significance was set at 5% ($p < 0.05$).

Results

TABLE 1 displays physiological and mechanical data. Power output at ANT corresponded to $82\%P_{MAX}$, whereas HR at ANT corresponded to $85\%HR_{MAX}$.

Subjects HR_{ON} was adjusted by a first-order exponential fitting, whereas HR_{OFF} was modelled by a second-order exponential fitting (TABLE 2); except for three subjects that, after 400 s of exercise interruption, were absent of a steady-state in recovery cardiac kinetics, demanding a linear adjustment. Linear, angular and determination coefficient values were, respectively[a]: Δ1: y = 112; α = -0.02; R = -0.42; Δ2: y = 103; α = -0.05; R = -0.54; e Δ3: y = 110; α = -0.02; R = -0.31. For all others, angular coefficient was ≤ ± 0.01.

TABLE 3 presents recovery HR and $[La]_b$ partial values. Although TT_{3km} power output was only $49\%P_{MAX}$, effort was sufficient to elicit significant increments in $[La]_b$ and HR, with no difference from the observed at $TLimP_{MAX}$, as well as $[La]_b$. Finally, no correlation was found between recovery HR and $TlimP_{MAX}$, P_{MAX} or TT_{3km} performance.

TT_{3km} mean power was 143 ± 35 W ($49\%P_{MAX}$) and total time was 534 ± 195 s. The variables obtained during $TLimP_{MAX}$ and TT_{3km} showed a tendency for association, so that subjects with faster performances also demonstrated higher P_{MAX} (r = -0.71 and p = 0.07). Additionaly, a positive correlation between $TLimP_{MAX}$ and time constatnt for cardiac on response (r = 0.95 and $p < 0.01$) and a negative correlation between $TLimP_{MAX}$ and the first time constatnt for cardiac off response (r = -0.67 and p = 0.04) were verified. Though, no association was found between HR_{ON} and HR_{OFF} and TT_{3km}[b] .

TABLE 1 - Cyclists physiological characteristics.

Variables	Mean	± SD
HR_{MAX} (bpm)	180	15
P_{MAX} at $TLimP_{MAX}$ (W)	292	37
P_{MAX} (W.kg-1)	4.0	0.8
ANT (W)	239	39
HR ANT (bpm)	153	14
$TLimP_{MAX}$ (s)	403	151

HR_{MAX} = maximal heart rate; P_{MAX} = maximal power output expressed as absolute and relative; ANT = anaerobic threshold; $TLimP_{MAX}$ = time to exhaustion at power output corresponding to P_{MAX}, expressed in seconds (s); $HR_{TLimPmax}$ = maximal heart rate at TLimPmax test; * = difference in relation to HR_{MAX} at TLimPmax test. Power output at TLimPmax corresponds to P_{MAX}, therefore, both are presented in the same line.

TABLE 2 - Heart rate and blood lactate concentration following TLimPMAX and TT3km.

Variables	***On*** **Kinetics**		***Off*** **Kinetics**	
	Mean	**± SD**	**Mean**	± SD
BL (bpm)	108	10	101	12
A1 (bpm)	66	15	37	9
T1 (s)	124	53	81	24
A2 (bpm)			38	9
T2 (s)			92	17

BL = HR baseline values, A1 and A2 = HR increase/decrease amplitudes; T1 and T2 = time constant for cardiac response kinetics. HRoff was limited to 400 s for three subjects (n = 3). For all others, time constant for recovery HR was 600 s (n = 4).

TABLE 3 - Cyclists physiological characteristics.

	HR (bpm)		**$[La]_b$ (mmol.l^{-1})**	
	$TLimP_{MAX}$	**TT_{3km}**	**TLimPmax**	**TT_{3km}**
Imme.	175 ± 11	176 ± 14	8.84 ± 2.01	8.33 ± 2.16
1-2 (min.)	124[a] ± 15	118a ± 16	9.98 ± 1.62	8.89 ± 2.67
3-4 (min.)	106[a] ± 12	104a ± 15	10.15 ± 1.55	8.94 ± 2.76
5-6 (min.)	102[a,b] ± 11	103a ± 13	9.90 ± 1.59	8.65 ± 2.76

Recovery $[Lac]_b$ was measured immediately after interromption of effort, and at 1, 3, and 5-minute post-effort; HR was measured during the final five seconds before interrumption of effort, and at 2, 4, and 6 minutes of recovery. For all analysis, $p < 0.05$; a = significant difference in relation to the value immediately after interromption of effort; b = significant difference in relation to the second minute.

Discussion

The main results from the present study demonstrated a tendency for association ($p = 0.07$) between $TLimP_{MAX}$ and TT_{3km} performance. Moreover, significant correlations between $TLimP_{MAX}$ and time constants from HR on and off kinetics were verified. The findings suggest that the association between $TLimP_{MAX}$ and TT_{3km} performance may be mediated by the cardiovascular system, although no direct correlation was found between HR on and off kinetics and TT_{3km} performance.

Comparing our results with other studies determining TLim using VO_{2MAX}, it is observed that the duration of the exertion tolerated by subjects from the present study is similar to what is described in literature (3 - 8 minutes)[29].

For example, when analyzing TLim of physically active cyclists, Basset, Billaut and Joanissi[30] observed TLim values of 235 ± 84 s. On the other hand, Billat et al.[31] reported TLim values of 222 ± 91 s for professional athletes. Considering the similar TLim duration on the aforementioned studies[30,31], and that the participants of the present study presented higher TLim values than the reported by Basset, Billaut and Joanissi[30], it is reasonable to suggest that, in addition to aerobic fitness, other factors may influence TLim duration. Zogati et al.[32] evidenced that pedaling cadence may also influence the duration of time that untrained cyclists are capable of tolerating maximal intensity efforts (373 ± 55 s vs. 234 ± 27 s at 40 and 100 rpm, respectively). This way, different cadences may influence time duration that individuals are capable of tolerating maximal exertions to exhaustion.

Between-subject coefficient of variation in the present study (37%) was higher than the reported in literature (25%)[6]. This indicates that, supposably, $TLimP_{MAX}$ presents similar dynamics to TLim established using VO_{2MAX}, however, $TLimP_{MAX}$ reproducibility may be influenced by the elevated variability between subjects in our study. Thus, future research should analyze factors determining between-subject variations. In spite of differences, it is possible to conclude that $TLimP_{MAX}$ may be an alternative method for determining cycling performance in mid duration events, especially since sophisticated equipments and specialized human resources are not required for its assessement.

Our results also demonstrated that lower values of time constant from HR off response relate better to $TLimP_{MAX}$ indices, with on responses presenting the reverse dynamic. Therefore, HR kinetic parameters may be associated with cyclist capacity to sustain efforts in elevated HR_{MAX} percentages. Evidences indicate that autonomic balance is determinant in HR_{ON} and HR_{OFF} kinetics in maximal and supramaximal intensities[12, 33]. Borrensen and Lambert[34], and Javorka et al.[35] argued that subjects with better aerobic fitness present higher parasympathetic autonomic nervous system activity, which could result in higher values of time constant (T1) from HR_{ON} and positive relation between $TLimP_{MAX}$ and HR_{ON} kinetics. In other words, subjects with higher capacity of tolerating exercise to exhaustion may evidence slower vagal withdraw in the onset of exercise, for HR elevation in the transition from rest to onset of exercise would depend mainly on autonomic vagal withdraw[36].

It is importante to emphasize the high values of the first time constant for HR_{ON} in the present study (124 ± 53 seconds). For example, Sietsema, Daly and Wasserman[37] described time constants for HR_{ON}, in exercises at 150 W in cycle ergometer, of 58 ± 10 seconds, while Bearden and Moffatt[27] verified T1 values close to 47 ± 11 seconds, for intensities above ANT. However, in both cases, time delay was calculated independently in the equations, while in the present study it was incorporated in T1 calculations. Moreover, in the aforementioned studies, exercise was performed in submaximal intensity, which could influence the cardiac kinetic response at the onset of exercise. Supposedly, the shorter the period of time required to elicit the chronotropic effects, the lesser the O2 deficit, and the larger the capacity to prolong exercise duration[27].

However, the capacity to meet muscular metabolic demand at the onset of exercise depends mainly of cardiac debt[38], which in turn is influenced by other factors beyond kinetic and autonomic cardiac response, such as systemic volume and cardiac inotropic changes[39]. It may exist, thus, dissociation between HR_{ON} and cardiac debt responses[40], although our analyses are unable to empirically answer this question.

On the other hand, inverse association between TLimPMAX and HROFF first time constant could indicate that individuals capable of achieving higher maximum mechanical power, and tolerate prolonged periods of maximal exercise to exhaustion, would also evidence higher parasympathetic autonomic contribution, considering that HR_{OFF} is influenced especially by this ANS division[41]. This way, in both situations, parasympathetic division seems to have significantly influenced HR kinetic response. Previous studies indicated that HR_{OFF} may be an important parameter to verify changes in performance in long[42] and mid[43] duration time trial tests. In the present study, HR kinetic parameters were only associated with aerobic fitness and cyclist capacity to tolerate longer periods of exercise at maximal intensities. In other words, cardiac kinetics may be sensitive to changes in aerobic fitness, contributing to training prescription and evaluation focused on changes in maximal aerobic power.

Evidences are unable to explain the absence of correlation between HR kinetic response, on and off, and TT_{3km} performance, although it is possible to deduce that cycling performance in mid duration events depends on the cyclist capacity to tolerate efforts at maximal intensity. Considering that the tests were performed simulating a 2% incline, it is possible that other factors besides cardiovascular responses influence subject performance. For example, Antón et al.[44] evidenced that short duration uphill climb performance of cyclists was influenced by P_{MAX} relative to body mass. Richard Davison et al.[45] sugested that mean power output in 30-sec Wingate test would also be a performance predictor for cyclists in short and mid duration events, especially for hill climbing experts.

Considering that mean power output in Wingate test as well as the capacity of tolerating effort intensities at P_{MAX} may be influenced by cyclist anaerobic capacity, it seems reasonable to suppose that correlation between $TLimP_{MAX}$ and TT_{3km} performance may be assessed by anaerobic metabolism. Elevated values of post-exercise blood lactate indicate a significant contribution from glycolytic pathway to provide the energy demands in TT_{3km}. In other terms, even if $TLimP_{MAX}$ was influenced by HR kinetic dynamics, performance in TT_{3km} would be influenced by the capacity of producing and sustaining maximal efforts.

Finally, 2% incline during TT_{3km} performance would be the main explanation for the difference in power output registered during the test (49%P_{MAX}). As Richard Davison et al.[45] argue, a 1% incline at the slope gradient may reduce professional cyclist power or speed in 11%. Recreational cyclists, as in the present study, could present reductions even more significant. The choice for adopting the incline for the TT_{3km} test was based in factors that may influence cyclist performance. On flat terrains, aspects like team strategy or peloton formationa[c] may be preponderant for performance, while uphill performance may depend mostly on individual aspects, especially the capacity of producing power output to surpass slope gradient. To apply a slope gradient may emphasize the importance of individual factors to performance.

Some limitations from the present study must be emphasized. A larger sample (n > 7) or composed of highly trained cyclists could elevate the level of significance evidenced in the present study. For example, Balmer, Davison and Bird[8] verified a relationship between Pmax and time trial performance, although in a distance much superior to the analyzed in the present study (16.1 km). The authors argue that Pmax would explain 98% of the subject capacity to tolerate high intensity efforts during a time trial, and almost 21% of results characteristics to task duration. However, they suggested that this could be a result of the heterogeneity of the group, so that the smallest correlations between our cyclists could be not only differences in protocol, but also the heterogeneity of the group.

In resume, $TLimP_{MAX}$ seems to be associated with cyclists performance in mid-duration time trials, although the affirmation contains reservations concerning the level of significance found (p = 0.07). Additionally, the association between HR kinetics and $TLimP_{MAX}$ suggests that the ability of cyclists to tolerate higher Pmax values and longer periods of maximum effort until exhaustion may be measured by the HR response kinetics. Future investigations to clarify the relationships between $TLimP_{MAX}$, HR kinetics and performance would characterize a profitable field of research.

Notes

a. Δ = subject. For all analysis p < 0.01.

b. Correlation indices between TT3km performance and HRON parameters (A1 and T1) were, respectively: r = -0.01 and p = 0.99; r = -0.24 and p = 0.60. For HR_{OFF}, whose pattern was biexponencial, A1 and T1 values were: r = -0.10 e p = 0.83; r = -0.06 e p = 0.89; while for A2 and T2: r = -0.06 e p = 0.89; r = -0.30 e p = 0.50. For all analysis, significance level was set at 5%.

c. According to Richard Davison et al.[45], cyclists positioning in line may dispend 26 - 39% less energy than cyclists leading the peloton formation, due to air drag.

Acknowledgement

I would like to thank the attentive reading and valious contributions from Prof. Dr. Rômulo Bertuzzi to the present study, without which it would be impossible.

Resumo

Tempo limite na potência aeróbia máxima, cinética da frequência cardíaca e desempenho em teste de ciclismo contra-relógio de 3 km.

O desempenho de ciclistas em tarefas de média duração parece estar associado a diversos fatores, incluindo potência aeróbia máxima (Pmax), frequência cardíaca (FC) e seus parâmetros cinéticos e a capacidade de tolerar esforços máximos até a exaustão (TLimPmax). Desse modo, o objetivo do presente estudo foi analisar possíveis relações entre TLimPmax e desempenho num teste contra-relógio de ciclismo de 3 km (CR_{3km}). Sete ciclistas participaram desse estudo, executando os seguintes testes com um intervalo mínimo de 48 h: (1) familiarização inicial e avaliações antropométricas, (2) teste máximo progressivo até a exaustão, (3) teste TLimPmax, e (4) teste CR_{3km}. Houve uma tendência de sujeitos com maiores valores de TLimPmax executarem o CR_{3km} em menor tempo (r = -0,71; p = 0,07). Evidenciou-se correlação positiva entre TLimPmax e constante de tempo da FC no início do exercício (r = 0,95 e p < 0,01) e negativa entre TLimPmax e primeira constante de tempo da FC de recuperação (r = -0,67 e p = 0,04). A tendência a associação entre o TLimPmax e o desempenho no teste CR_{3km} poderia indicar que essa variável talvez possa ser utilizada na avaliação de ciclistas – embora com ressalvas - já que a correlação não foi significante. Futuras investigações tentando esclarecer as relações entre TLimPmax, cinética da FC e desempenho caracterizaria um campo profícuo de pesquisa.

Palavras-chave: Frequência cardíaca; Potência aeróbia máxima; Contra-relógio; Ciclismo.

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